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The use of Lincompex on h.f. links for overseas broadcasting

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RESEARCH DEPARTMENT

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Summary

This report considers the application of the Lincompex system to h.f. links for distributing BBC programmes to some of the overseas relay stations. Laboratory tests and field trials of prototype equipment have been carried out. Results have been sufficiently encouraging to justify more extended trials.

1. Introduction

The BBC External Services employ relay transmitter stations, which receive much of their programme material from the United Kingdom, not only by reception of broadcast transmissions but also by means of h.f. radio links using single sideband transmission. The signal received by a relay station may be subject to the various impairments typical of h.f. transmission paths. These impairments include the variation in signal level caused by the changing propagation conditions, and the addition of interfering signals and random noise. The latter is most likely to arise during fading of the signal, when the a.g.c. increases the receiver gain, and hence the noise at the output.

In order to overcome some of these difficulties arising on h.f. radiotelephone circuits, the British Post Office developed the Lincompex system of signal processing.[1] This is a pilot-tone compandor system in which the pilot is an f.m. signal at the upper end of the transmitted audio band.

The system is now well established for h.f. telephony using 3 kHz total bandwidth, and extensive trials by the Post Office as well as operational experience have demonstrated conclusively that the intelligibility of speech on a noisy h.f. link is significantly improved by the Lincompex processing.[2] It is therefore reasonable to suggest that a useful improvement may be obtained on broadcasting links. However, it is possible that the additional bandwidth required for a broadcasting link may introduce noise components which are not masked by the speech components to the same extent as in a telephone link. Moreover, while good intelligibility of speech is a very important objective for overseas broadcasting, it is by no means the only criterion for assessing the performance of a link. In particular, the subjective assessment of music may be very different from that applicable to speech. It was therefore desirable to carry out tests to evaluate the benefit to be expected from such a system for broadcasting purposes. For this purpose prototype equipment was made to a BBC specification.

2. Outline of system

A simplified block diagram of the equipment is shown in Fig. 1. The incoming programme is split into two paths, viz., a programme path and a control path. In the control path the amplitude of the signal is assessed at syllabic rate, i.e., the amplitude variation may have a frequency component of not more than about 100 Hz. The corresponding voltage is used to control the frequency of the pilot-tone oscillator, and also to compress the signal in the programme path by 40 dB. The compressed programme and the pilot tone are then added, and the composite signal fed to the transmitter. At the output of the receiver, the two components are again split into two paths. In the programme

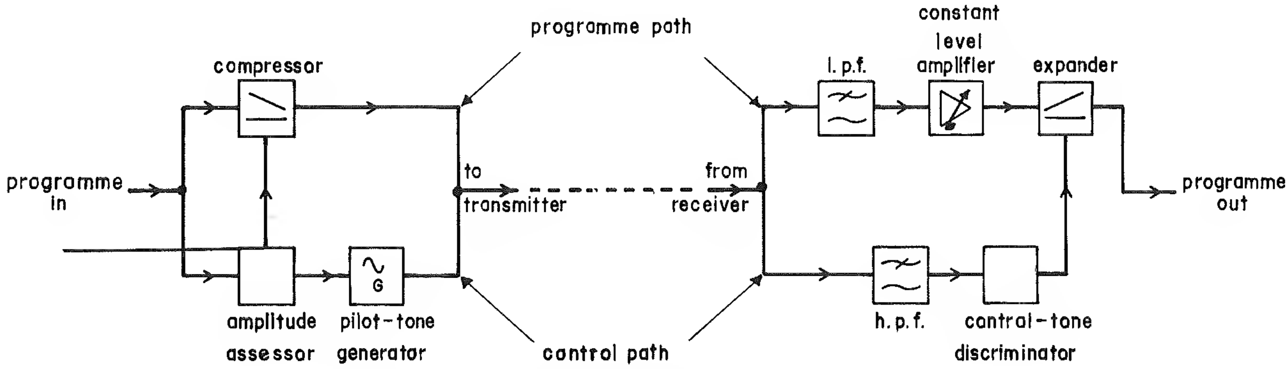

Fig. 1 - Simplified block diagram of Lincompex system

path, a constant-level amplifier provides a constant output for a 20 dB variation in the input level. The signal is then fed to a 60 dB expander, which is controlled by the voltage derived from the pilot-tone discriminator in the control path. Provided that the characteristics of the compression before transmission and the expansion after reception are accurately matched, the original dynamic range of the programme is restored.

3. Audio bandwidth and pilot-tone frequency

In the original Limcompex equipment designed for telephony, the overall channel bandwidth is restricted to 3 kHz, and the pilot tone is placed near the high-frequency end of the speech band, at 2·9 kHz. It was decided that the same principle should be adopted for the prototype broadcasting equipment, so that the minimum amount of re-design would be necessary. For h.f. broadcasting an audio bandwidth of 5·5 kHz is sufficient for normal requirements, so the control tone in the broadcast prototype was specified to be centred on 5·7 kHz, and the maximum frequency in the programme chain was restricted to 5·5 kHz (the response at this frequency being less than −55 dB). Thus, the detailed specification of the various parameters was largely based on a two-to-one scaling of the Post Office telephony parameters.

4. Dynamic characteristics

One of the important parameters of a compandor system is its 'attack time', i.e., the time taken for the compressor (and expander) to respond to a sudden change of input level. The choice of attack time is necessarily a compromise.[3] If it is too long, the compandor fails to be effective, while if it is too short, the compandor will tend to distort low-frequency components of the programme. In the tentative specification for the broadcast prototype, it is required that transient effects should be substantially complete after about 4 ms.

5. Tests on prototype equipment

5.1. Objective measurements

No attempt was made to perform a complete set of objective tests, because within the limited time available it was thought to be more important to investigate subjective effects in practical operating conditions. However, some measurements of the response to a burst of 1 kHz tone were made, and Fig. 2 shows the overall response of the Transmit and Receive equipment connected in tandem. It may be seen that a low-frequency ripple is superimposed on the burst waveform. The shape of the waveform, and other supplementary measurements, indicate that the programme is delayed by a few milliseconds relative to the control voltage at the expander. There are delay networks (not shown in the block diagram of Fig. 1) in the programme path of the Transmit and Receive equipment to ensure that the programme and corresponding control voltage are in the correct time relationship, and it would appear that somewhat too much delay has been introduced in the prototype equipment. By reducing this delay, and making some adjustment to the time constant of the expander control circuit, it was found to be possible to change the burst response to approximately that shown by the broken line in Fig. 2.

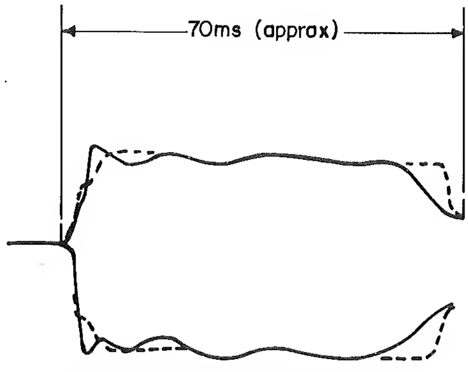

Fig. 2 - Response to tone burst
—— Unmodified prototype equipment - - - After modification

5.2. Subjective laboratory tests

Listening tests were carried out in the laboratory with the Lincompex Transmit and Receive units connected 'back-to-back', to assess impairments introduced by any instrumental imperfections. The programme material was a tape recording containing speech and a wide range of music which may be expected to be particularly sensitive to transient effects. In general, the performance of the equipment was fairly satisfactory. In particular, it was very free of low-frequency breakthrough from the control path, which is a difficulty often associated with compandor systems. The main defects observed during these critical listening tests were as follows:

Firstly, there was some audible breakthrough of the f.m. control tone into the programme. Secondly, a 'crumbling' effect occurred on some transients. This was believed to be due to some form of transient noise in the Transmit compressor. Thirdly, there was a tendency to 'blasting' of high-level sibilants. The effect of the control tone breakthrough was overcome, for the purpose of carrying out other tests, by inserting a sharp-cut low-pass filter at the output of the system. The remaining defects, although sufficiently important to warrant further investigation by the manufacturer at a later date, were not serious enough to prevent field trials being carried out on an h.f. link to investigate any unexpected problems which might arise under operational conditions.

5.3. Field trials

A number of field trials were carried out involving h.f. transmission paths. In some of them, a scattered signal was received from a transmitter at a distance of about 137 km. Other tests involved a path totalling 6830 km. For the latter tests, the compressed signal was transmitted from the United Kingdom to Ascension Island, where it was received and re-transmitted on a different frequency without special processing. This relayed signal was received in the

U.K., and processed by the Lincompex Receive equipment. Thus, the tests were fairly stringent, inasmuch as there was frequently a combination of low signal strength and deep fading.

The first trials showed that the most serious limitation of the prototype equipment was the loss of control tone during the deep fades. This resulted in loud bursts of noise of a very objectionable nature. The manufacturers then supplied an improved form of control tone discriminator. This had greater sensitivity, and was less prone to lose control during fades. Moreover, the new circuit was so arranged that when drop-outs did occur, the audio output level was prevented from increasing unduly, so that the noise burst was less objectionable. The use of the new discriminator considerably improved the performance of the system, although under adverse propagation conditions the effect of control tone drop-outs was still noticeable.

Subsequent to the improvement in the control tone circuits, the most significant effect of the Lincompex processing was observed to be the volume-dependent noise which is fundamental to a compandor system, i.e. the noise rises and falls with the level of the programme. On some types of music, the subjective effect of this type of noise can be more objectionable than a continuous noise background.

One method of reducing the effect of volume-dependent noise is the application of pre- and de-emphasis of the audio signal.[4] Some of the later tests included pre- and de-emphasis, using CCITT characteristics[5] (reproduced in Fig. 3), having 0 dB insertion loss at 1 kHz. These tests indicated that some benefit may be expected from using pre- and de-emphasis in association with Lincompex, particularly on musical items. Care must be taken, however, to ensure good linearity of amplifiers in the equipment to avoid the possibility of 'blasting' on sibilants.

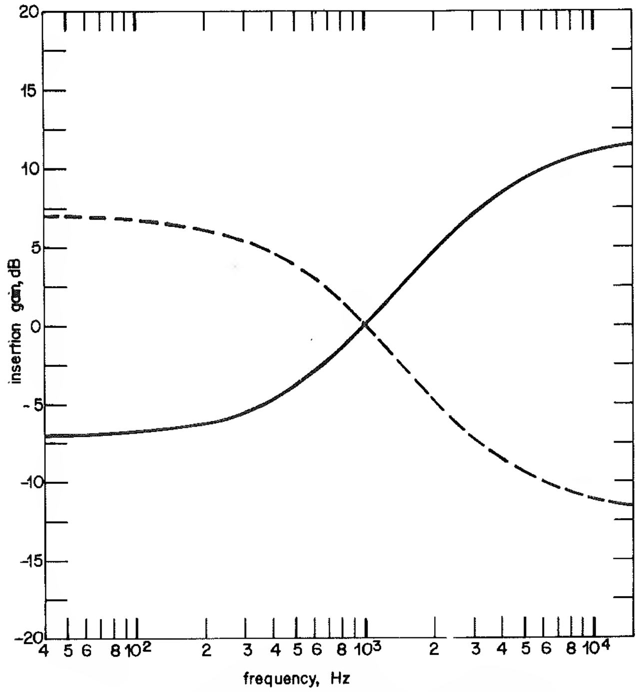

Fig. 3 - Pre- and de-emphasis characteristics
—— Pre-emphasis — — — de-emphasis

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Overall, the field trials indicated that the Lincompex system provided a useful reduction in the subjective impairment caused by noise on speech transmissions, and this was achieved with no significant change in quality. Without the use of pre-emphasis, there was on average a slight deterioration in the subjective quality of musical items, largely because of volume-dependent noise effects. This deterioration was prevented by using pre-emphasis, while at the same time the benefit on speech was preserved.

It is possible that the quality with Lincompex was at times slightly impaired by the minor instrumental deficiencies described in Section 5.2, so that a somewhat greater overall benefit might be expected with the production equipment.

6. Conclusions

As a result of the preliminary experiments with the prototype Lincompex equipment, a few instrumental defects have been pointed out. It has been found that the tentative specification drawn up by the BBC Research Department is substantially correct, but it may be necessary to slightly reduce the audio bandwidth to reduce breakthrough from the control tone.

Pre- and de-emphasis of the audio signal is believed to provide a useful benefit in reducing the subjective effect of volume-dependent noise.

The benefit to be obtained from the use of Lincompex on h.f. links is unlikely to be as marked as that achieved on radiotelephone circuits, but there is evidence to suggest that there would be sufficient benefit to justify more extensive trials by the BBC.

7. References

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